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Materials and Techniques of *Art Nouveau* Architecture in Italy and Portugal: a First Insight for a European Route to Consistent Restoration

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Abstract

The results of the investigations on building materials and techniques of Casa Major Pessoa, a typical *Art Nouveau* construction in Aveiro (Portugal), and two coeval *Art Nouveau* buildings in Bologna (Italy) are presented as a methodological contribution to the restoration of this kind of buildings. This is the first step to ascertain the existence of a common thread between local materials, technologies and architecture in European countries at the same period. A holistic approach was adopted: materials were investigated along with architectural, structural and technological features, in order to achieve a first insight into the *Art Nouveau* architecture in Europe in particular for its consistent restoration without loss of historical memory.

Keywords: *Art Nouveau* architecture, surface decay, restoration, building materials, construction technologies

Werkstoffe und Technologien der Jugendstil Architektur in Italien und Portugal: Ein erster Schritt auf einem europäischen Weg hin zu einer konsistenten Restaurierung

Zusammenfassung

Werkstoffe und Bauweisen, die beim Bau der Casa Major Pessoa, ein typischer Bau des Jugendstils in Aveiro (Portugal), und beim Bau von zwei Gebäuden, die ebenfalls im Jugendstil etwa zur gleichen Zeit in Bologna (Italien) errichtet wurden, zur Anwendung kamen, wurden untersucht. Die Ergebnisse werden in dieser Veröffentlichung beschrieben. Sie stellen einen methodologischen Beitrag zum Restaurieren dieser Art von Gebäuden dar. Dies ist ein erster Schritt, um die Existenz einer engen Verbindung zwischen den lokalen Werkstoffen und Bauweisen einerseits und der Architektur in europäischen Ländern andererseits in etwa im gleichen Zeitraum heraus zu stellen. Ein holistisches Vorgehen wurde gewählt: die Werkstoffe wurden parallel mit den architektonischen, strukturellen und technologischen Aspekten untersucht, um einen ersten Einblick in die Jugendstil Architektur in Europa zu gewinnen, um darauf aufbauend eine konsistente Restaurierung entwickeln zu können, bei der das geschichtliche Gedächtnis nicht verloren geht.

Stichwörter: *Jugendstil Architektur; Oberflächenschäden; Restaurieren; Werkstoffe des Bauwesens; Bauweisen*

1 Scope of the Paper

Art Nouveau generally describes different avant-garde movements which shook Europe at the end of XIX and beginning of XX century, having in common the boost for a renewal in art and architecture [1-4]. This renewal actually began in the applied arts (e. g. William Morris "Arts and Crafts") [1, 5] and industrial design, where flower-style decorations and suggestions from the Eastern art diffused.

Architectural innovation was supported by the newly developed industrial materials (steel, reinforced concrete, glass, etc.) [2], construction technologies and structure highlighting, in a general riot against academic and traditional styles [6]. Nevertheless, the architectural current differently developed in the European countries [7] (*jugendstil*, *sezessionstil*, *arte nova*, etc.): Horta and van de Velde in Belgium, Wagner, Olbrich and Hoffmann in Austria, Berlage in the Netherlands and other architects all over Europe interpreted in different ways the new idea of architecture, often supported by social push too.

In Portugal the new style diffused quite late and was strongly opposed and generally rejected by traditional architects and hence relegated to the decorative field (banisters, tiles, etc.). Yet, in Aveiro the movement arrived in a period of renaissance for the city itself, after more than a century of commercial and economic isolation caused by the lowering of the water level in the channels linking the city to the sea, and it was adopted as the architectural language of the new prosperous period [8].

In Italy the *Art Nouveau* movement was practically free from social implications and it was restricted essentially to the so-called *liberty* (or *"floreale"*) style, as a break-through with tradition; although brief, it was an important experience with valuable architects, e. g. R. D'Aronco and G. Sommaruga [1-4]. In Bologna the modernism arrived later, with the eclectic style still dominant, so its outgrowth was only partial [9]. However, local eclectic architects were fascinated by the new style and some hybridisation between the existing and new style occurred: as in France [1], the *Art Nouveau* language became an element of eclectic repertory; entire streets were bounded by *liberty* villas and buildings, echoing also the garden city experience.

Comparative study between coeval buildings (early XX cent.) in Aveiro (*Casa Major Pessoa*) and Bologna (*Chalet Restaurant* of the *Giardini Margherita* [Margherita Gardens] and *Sacro Cuore* [Holy Heart] Church) appeared very useful to approach basic hints for restoration procedures of *Art Nouveau* heritage in Europe. Further studies are still in progress on other *Art Nouveau* buildings in Europe, in order to get an overall sketch of this troubled architectural age.

As a matter of fact, the restoration and conservation of *Art Nouveau* heritage in Europe rise several common problems. Firstly, the polluted urban environment leads today to severe materials decay and therefore the maintenance works are today performed with lack of concern in the materials features as related to environmental injuries [10]. Secondly, the original materials and technologies ("decorative cements", artificial stones, surface texture and finishing, etc.) are often lost during restoration works themselves, due to (i) the lack of workmanship and knowledge of the materials/technologies of the modernist and *Art Nouveau* (A.N.) architecture, which causes fully inconsistent results in restoration works; (ii) the feeling that the *Art Nouveau* movement, being often self-contradictory (particularly in its start), today doesn't deserve full recognition in restoration, thus often loosing fine A. N. characteristics and – together – its renewal push itself; (iii) the lack of concern about the building site and the effects of the environmental blighting pollutants (although they are in the public domain the world over) on the Architectural Heritage.

Moreover, the A. N. age was characterised by deep social transformations from tradition to innovation and, hence, from craftsmanship to series-production up to industrialisation, leading architecture to the modern movement, which poses quite new problems for a consistent restoration.

The three different *Art Nouveau* buildings in Aveiro and Bologna were selected and analysed as a first approach to widen their historical view up to the architectural features as well as original construction materials and techniques within the European *Art Nouveau* frame, to contribute to their restoration and recovery according to cultural heritage preservation principles ("Venice Charter - International charter for the conservation and restoration of monuments and sites" of 1964 and "Italian Restoration Charter" of 1972 and elsewhere [11-12]). As the buildings were aimed to very different functions (a wealthy dwelling in Aveiro and, respectively, a recollection and a pleasure meeting point), construction materials and techniques were subject to thorough characterization also to disclose if they might be purposely chosen according to their final use, to strengthen their final vocation.

2 Casa Major Pessoa in Aveiro

Casa Major Pessoa (Fig. 1), designed by Francisco Silva Rocha and Ernesto Korrodi, was built in 1907-1909 and is a representative example of *arte nova* architecture in Aveiro. The original two storeys were integrated with a third one in the same style [8, 13] a few years after (Fig. 1), likely reusing the main façade's stone decorations. The plan is long and narrow, in line with the gothic arrangement of the block. The main façade (7 m wide) is towards the Aveiro's Central Channel.

In 2005 both structural and non-structural elements of Casa Major Pessoa were in poor conditions. Due to the surrounding environment and poor maintenance, the building exhibits serious cracks and deterioration problems that threaten its structural integrity. Under these circumstances, the *Câmara Municipal de Aveiro* bought the historical house and took in its hands the building preservation. The initial step was to evaluate the state of the building and identify the degradation causes. Building evaluation survey was undertaken to provide the basis for the conservation appraisal [14].

The critical aspects influencing the durability of the building and its global stability were identified: 1) degradation of the façade limestones (Fig. 2-3), mainly due to environment exposure; 2) excessive deformation of the façade due, on the one hand, to changes in the soil foundation conditions in the vicinity of the building and, on the other hand, to the detachment between the façades and the load-bearing walls; 3) infiltrations in the wood roof and floor systems due to bad performance and lack of maintenance of the roof coverings and drainage systems; 4) moisture in structural masonry walls; 5) crushes in some walls due to high stress concentrations.

Immediately after the building's purchase by the Aveiro Municipality, the rehabilitation process was initiated, in order to safeguard the building's rich façade decorations, as well as the *azulejos* (traditional hand-painted ceramic tiles [15], not decayed) at its interior, in the typical Portuguese *arte nova* style (Fig. 3).

2.1 Architectural, Structural and Technological Features

The house was built and refurbished with a plenty of structural materials, in line with the local building tradition: mud bricks (*adobe*, a simply dried mixture of clay and hay), fired clay bricks and wood.

The structure of the building follows the construction characteristics of the beginning of the last century in the Aveiro region, namely:

- Load bearing walls (mid-walls, perpendicular to the façades) with a large diversity in thickness and materials: adobe, brick masonry, *tabique de fasquio* (a wood structural wall covered with plaster);
- Façade composed by heavy limestone blocks, laboriously hand-carved, supported by slim stone columns at the ground floor;
- Wood as main structural material for roof (covered by Marseilles tiles);
- Floors constituted of wood beams parallel to the façades, bearing directly on the lateral walls.

Figure 1: Casa Major Pessoa: south front presently (left) and in 1909 [13] (right)

Figure 2: Casa Major Pessoa: materials decay in the south front open lodge at the ground floor (left) and a detail of the limestone decorations deep decay (right)

Figure 3: Casa Major Pessoa: materials' decay in north front (left) and *azulejos* (right)

An irregular structural system was created when an additional storey was added to the original building. It is noteworthy that the roof structure is composed by five main wood trusses, four of them non-symmetrical, resting on the main load-bearing walls on one side and on a wood load-bearing wall on the other one. In order to support the roof trusses, in the third storey a plastered tabique wall was built. At the third floor and parallel to the wood beams, steel beams were installed in order to share the loads coming from the roof structure.

The overall arrangement of floors, walls and architectural texture is shown in Fig. 4.

2.2 Construction Materials and Techniques

2.2.1 Experimental Part

Several samples of structural and finishing materials were withdrawn from Casa Major Pessoa, catalogued and investigated, according to a previous diagnostic procedure developed on ancient architecture [16-24].

Samples composition was determined by X-ray diffraction (Philips Diffractometer PW 1830) and $CaCO_3$ content by a Dietrich-Frühling apparatus. The pore size distribution was determined by mercury intrusion (Porosimeter 2000 Carlo Erba with a

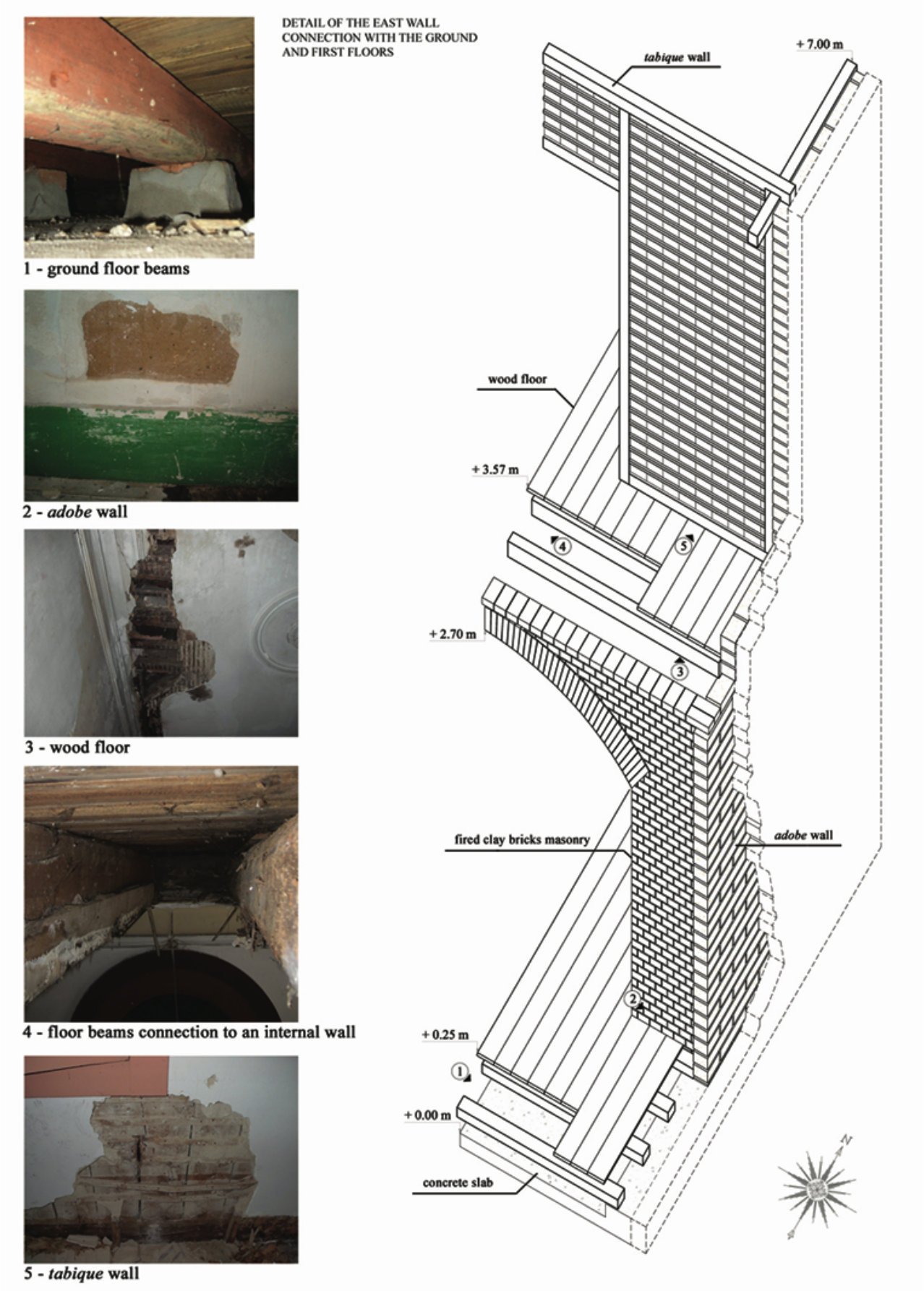

Figure 4: Casa Major Pessoa: sketch of the east wall's connection to the ground and first floors

Table 1: Casa Major Pessoa: plasters description

sample	type and location	layers (from the inner surface)	thickness
A1 - a	Plaster (internal brick wall, ground floor)	*Layer 1*: yellow-grey mortar	12 mm
		Layer 2: white mortar	4 mm
A1 - c	Plaster behind the *azulejos* (internal brick wall, ground floor)	*Layer 1*: yellow-grey mortar	12 mm
A2	Plaster (internal brick wall, ground floor)	*Layer 1*: yellow-grey mortar	9 mm
		Layer 2: yellow-grey mortar	6 mm
A3	Plaster (first floor *tabique* structural wall)	*Layer 1*: yellow-grey mortar	20 mm
		Layer 2: yellow-grey mortar	8 mm
		Layer 3: white mortar	4 mm
A4	Plaster (second floor *tabique* structural wall)	*Layer 1*: yellow-grey mortar embedding rough vegetable fibres	25 mm
		Layer 2: yellow-grey mortar	15 mm
		Layer 3: white mortar	3 mm
		Layer 4: white painting	<1 mm
S0	Plaster (ground floor wood ceiling)	*Layer 1*: yellow-grey mortar	up to 50 mm
		Layer 2: yellow-grey mortar embedding the wood beams	25 mm
		Layer 3: white mortar	2 mm
		Layer 4: white painting	<1 mm
S1	Plaster (first floor wood ceiling)	*Layer 1*: yellow-grey mortar	10 mm
		Layer 2: white mortar	5 mm

Fisons Macropore Unit 120). Chlorides, sulphates and nitrates content was determined by extraction with boiling water, filtration and ion chromatography (Dionex ICS-1000). The plasters were firstly separated into their different layers (Table 1) and manually disaggregated to obtain the true grain size distribution of the constituting phases: the fine and the coarse fractions, usually containing respectively binder and aggregate, were separately characterised as above [25].

2.2.2 Results and Discussion

The plasters (Table 1) exhibited a great homogeneity: they are all made of lime binder with quartz sand (only scarce feldspar traces) and are characterised by large thickness (up to about 5 cm, Table 1) and high porosity (see, e. g., Fig. 5). The macropores are very abundant in the plasters, also due to the low amount of binder: after manual disaggregation only 15 wt % was found below 0.1 mm (Fig. 6). Thickness and porosity seem aimed to give the wall good thermo-acoustic performances, but they give also a large thickness with low weight to the slim *tabique* walls. Accordingly, the plasters are made by different layers only to obtain strong thickness and in fact the grain size difference among the layers is negligible (Fig. 6).

For hygiene and aesthetic purpose, the indoor plasters are finished with a thick layer of gypsum-limestone mortar (up to about 5 mm). The presence of raw vegetable fibres and ash in some plasters confirms their traditional preparation. The addition of vegetable ash to lime-binder mortars was advised since Vitruvius teachings against rising dampness [26], besides the well known use of ground fired clay brick, or "*potsherd*" (Italian "*cocciopesto*") [26], and pozzolan [26], a further sign of the architecture compliance to ancient construction rules.

The *arte nova* decorations in the south façade (Fig. 1-2) are made of typical Portuguese limestone ($CaCO_3 \approx 99$ wt%) with high open porosity (30 vol %). The remarkable amount of chlorides (at least 0.23 wt %) comes from the local marine spray and causes the overall material's decay so evident in Fig. 2 and 3.

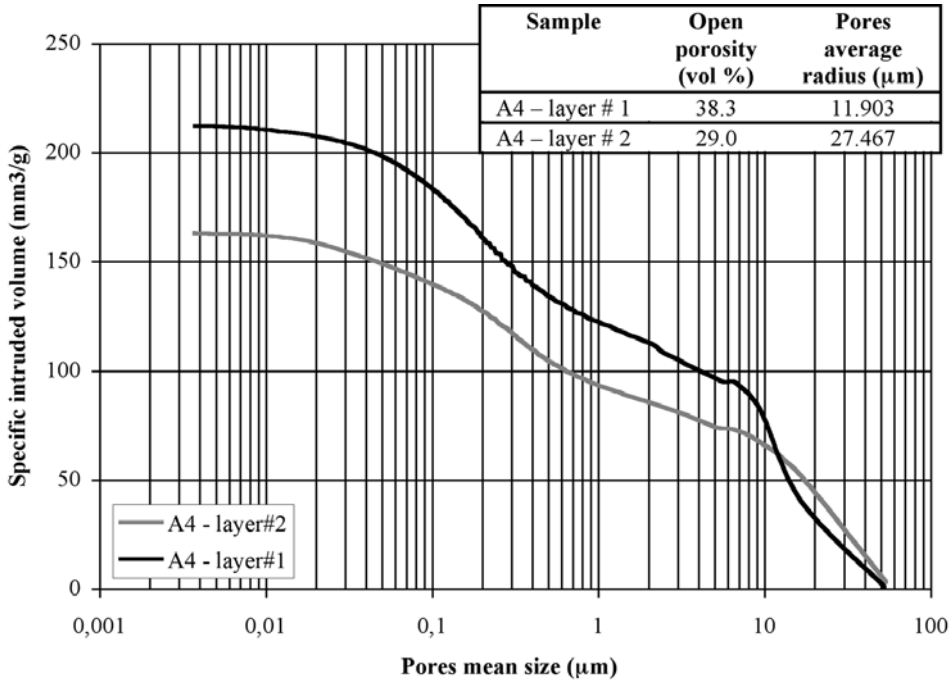

Figure 5: Casa Major Pessoa: pore size distribution in the layers 1 and 2 of A4 plaster

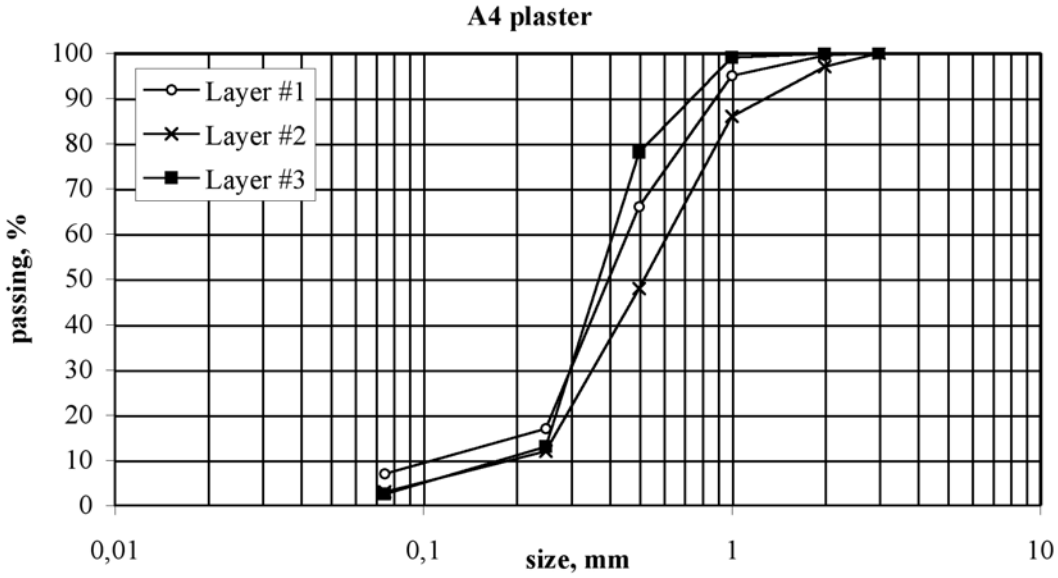

Figure 6: Casa Major Pessoa: grain size distribution in the three layers of A4 plaster

In conclusion, the materials of Casa Major Pessoa are those of the local building tradition and don't seem in any way to be influenced by the technological innovation of the early XX century. No traces of cement or artificial stones have been detected in the building ornaments and the modernity of the architecture was obtained only by means of wholly traditional materials, easily and cheaply available locally.

2.2.3 Mechanical Characterization of Load-bearing Walls and Façades

In order to investigate the constituent materials of the load bearing walls and to characterize their mechanical behaviour and strength, 26 cylindrical cores (diameter 9.0 – 10.4 – 15.0 cm) were extracted from the walls, perpendicularly to their external surfaces. From the inspection cores, 12 adobe cylindrical specimens, representing the pre-

dominant material in the load bearing walls, were prepared and tested in compression. Two different adobe types were found, corresponding to the two construction phases previously identified, but made of similar soil material. From the mechanical compression tests on the cylindrical specimens it was derived an average strength of 600 kPa for the adobe. In Aveiro region, traditionally, the composition adopted in the mortars (plasters and joints) was similar to that used in the adobe's production. Consequently, similar mechanical properties are verified for the adobe and mortars, as concluded in previous studies on these local materials (see, e.g., [27]). Therefore, 600 kPa can be considered, as reference strength, in the safety verification of the adobe load-bearing walls. From the analysis of the current stone in the structural components of the Casa Major Pessoa façade, its strength was estimated.

2.2.4 Safety Assessment of the Load-bearing Adobe Walls and Limestone Façades and Structural Recommendations for the Rehabilitation of the Building

As mentioned in Section 2.1, the main vertical structural system of Casa Major Pessoa is composed by adobe load bearing mid-walls, perpendicular to the limestone façades. The dead-load of the floors and roofs, as well as the live-loads acting on them, is supported by the adobe mid-walls. The façades are loaded, essentially, by their own weight.

Considering the structural system composition, described before, the vertical loads distribution and the strength estimation of each structural element, the safety of the structural walls and façades to the quasi-permanent vertical loads was evaluated.

From the stress distribution on the adobe load-bearing walls, a maximum value of 270 kPa was estimated. Comparing this maximum stress with the mean adobe strength of 600 kPa, a low safety factor was estimated for the adobe bearing walls. For the stone façade components, a larger safety factor was estimated, even for the slender columns at the façade's base, which support the total weight of the façade.

Even if, apparently, the structural safety of the load-bearing adobe walls and façades was guaranteed for the corresponding vertical loads implied, the severe damages observed in the connection between them, associated to the need of a much higher structural safety level, particularly for horizontal actions, demanded especial attention and measures in the strengthening design procedure.

In fact, during the inspections to the building, it was observed that the façades were completely detached from the adobe structural walls, due to differential creep, on the one hand, and to the foundations settlement, on the other hand. The poor soil foundation conditions in this point of the city of Aveiro must be remarked.

Thus, considering all these aspects and constraints, for the structural rehabilitation design of the building the following measures were recommended: on the one hand, to create a secondary system to connect the existing vertical components (adobe load-bearing walls and façades) and, on the other hand, to improve the global safety of the building to lateral loads, as those induced by vibrations, earthquakes and wind. A steel structural frame system, founded on piles, was adopted, which was completely embedded in the existing adobe walls, not to change the original architecture of the building.

2.2.5 Hints for Materials Restoration

Casa Major Pessoa allows to draw some useful hints for restoration from the materials characterization results, thus clarifying the need of a thorough materials diagnostics to perform a respectful restoration of the Portuguese Art Nouveau according to the materials nature and state.

Plasters

According to the decay mapping (not reported for brevity sake), Casa Major Pessoa exhibits: (i) portions of sound plasters, (ii) portions of decayed plasters, due to the presence of moisture from both infiltration and capillary rise, (iii) portions of lacking plasters, due to previous detachments. Considering that no decorative paintings are present on the plasters (figurative decorations are only in the *azulejos*) and that the present plasters date back to the building construction time (as confirmed by both historical and diagnostic investigation), the restoration of plasters should provide for:

- consolidation of the existing sound plasters, according to, e. g., the *minimum intervention* principle by Cesare Brandi [11]: as shown above, such plasters testimony how traditional technologies survived also during the A. N. age, thus deserving proper safeguard and consistent restoration
- restoration of the damaged plasters and filling of the lacking ones with compatible materials, as, e. g., recommended by the Italian *Carta della conservazione e del restauro degli oggetti d'arte e di cultura*

Figure 7: The *Palazzina* Liberty (left) and the *Sacro Cuore* Church (right)

(Charter of conservation and restoration of art and culture objects) of 1987, annex B [28], on the basis of the diagnostic survey results [25], by using binder and aggregate having the same nature of the pre-existing ones, choosing aggregate having the same grain size distribution of the pre-existing ones and reproducing the original plasters microstructure for a truly consistent restoration.

A final paint of the same kind of the existing one shall be applied where previously present.

Anyway a thorough graphic and photographic survey of the pre-existing and restored parts is recommended, for future reference.

Stone

As the façade decorations were found to be limestone made without traces of modern materials (cement, concrete), a feature not frequently noticed in other Art Nouveau cases in Europe, stone restoration procedures should follow the same as for the decayed stones in ancient architecture [29].

Hints come also from the materials diagnostics of the other Art Nouveau buildings here investigated, which will be very useful for a respectful materials restoration within a European Art Nouveau framework.

3 The Chalet Restaurant and the "Sacro Cuore" Church in Bologna

3.1 Architectural, Structural and Technological Features

The selected, representative buildings in Bologna (Fig. 7), dating back approximately to the same age as Casa Major Pessoa, i. e. the beginning of XX century, were both designed by Edoardo Collamarini, professor of drawing and architecture [30]. The first one, the so-called *Palazzina Liberty* (Liberty Villa) or *Chalet Restaurant* (Fig. 7) in the *Giardini Margherita* (Margherita Gardens), was built in the early years of XX century as refreshment point inside the newly-made city gardens [31]. At the time, the Chalet was referred to as "Italian styled" [32], but it is actually eclectic-styled, exhibiting liberty features as well as neoclassical echoes. The *Palazzina* is essentially made of fired clay bricks as structural material, while in the external surfaces it is enriched by decorative ornaments made of cement-based mortar and concrete. The lodges and terraces at the first and second floors were assigned to rest and leisure during the summer season and the internal large halls to parties and banquets.

Thanks to its position inside the Gardens, with scarce atmospheric pollution, the building is in fairly good state, even if some materials (masonry bricks, natural stones, finishing) exhibit decay; some recently restored parts are decayed, due to a poor compatibility between some restoration materials and the existing ones.

The second building in Bologna, the *Sacro Cuore* (Holy Heart) Church (1901-1912) [33] (Fig. 7), might be defined Byzantine-styled, but it is actually eclectic again, exhibiting gothic and Romanesque suggestions too. Shortly after the construction (1929), the dome collapsed and the upper part of the church was rebuilt, after some foundations strengthening. Later, in 1943, the building was damaged again by a bomb and restored just after the Second World War [34]. The Church square plan and the main central dome sided by two half-domes recall the Byzantine basilicas, as St. Sophia of Con-

Figure 8: Palazzina Liberty: the external brick joints containing potsherd, resembling traditional "*sagramatura*"

stantinople. The main structural material is fired clay brick, even if, after the dome's collapse and the war damages, some parts were strengthened by reinforced concrete structures (the foundations, dome and internal pillars), hiding them with bricks in order not to distort the overall architectural image. The façades' decorations are made of bricks, *cotto* tiles, concrete, natural stone and mosaic works.

Although the structural state of the church is fairly good, the external surfaces are somewhat decayed (exfoliation, black crusts, disaggregation, deposits, etc.), due to the high local atmospheric pollution, caused by the heavy traffic (the church is close to the railway station).

3.2 Materials and Techniques

Again, specimens of bricks, natural and artificial stones, mortars, plasters and finishings were withdrawn from the two buildings and characterisation was performed by the same above quoted techniques used for Casa Major Pessoa.

For the Palazzina Liberty, the results show that:

- modern materials are present: agglomerated cement-bound stones in the internal stairs, cement mortars and concrete in the lodge banister and other external decorative elements, often white painted (Fig. 7) in order to resemble marble (a 'noble' material not available locally).
- Together with modern materials, traditional and local ones are still abundant in the building. E. g., locally available sandstone was used for the house base and white painted, as above described. Local sandstone is a silica-lime-feldspar stone, characterised by a low calcium carbonate amount (about 33 wt %) and high porosity. Due to its scarce hardness and easy workability, it was widely used for ornaments in ancient Bologna architecture too. It is odd that such a material was used as building base, while cement concrete and mortars were mostly used for decorative elements: it suggests that cement-based materials were cautiously used at the time, due to the still scarce trust on them and their high cost. Recently the stone was locally repaired by cement mortar, which led to cracks and detachment, due to its microstructural poor compatibility with sandstone.
- The outdoor filling of the mortar joints of the fired clay bricks of the walls is made of lime and *potsherds*, added with silica sand as fine aggregate (Fig. 8), while the embedding mortar beneath is a common lime mortar with a silica-limestone sand. This external, brick-coloured filling gives the wall higher durability to outdoor environment and resembles the ancient "*sagramatura*". The *sagramatura* [35] was a very ancient surface finishing technique (typical of Bologna and of many other Italian cities), in which the newly built wall was continuously rubbed by a fragment of the same fired clay brick: in this way, the lime mortar gave rise to a fine mixture with the scraped brick powder and hence a very thin protective layer formed on the wall surface by harden-

Figure 9: The Sacro Cuore church: natural stone basis and a precast concrete column in the main façade (left). Ledge partially made of stone and concrete in the side façade (right)

ing. This layer strongly adheres to the substrate, gave it a good resistance to water (due to the pozzolanic activity of *potsherd* with lime) and gives a quite uniform colour effect without hiding the bricks texture.

- In the floors, cement-bound agglomerated stones are used near the traditional "*terrazzo*" floor.
- The fired clay bricks show no traces of calcium carbonate, revealing their industrialised production technology and, thus, high firing temperature.

For the Sacro Cuore Church, the experimental results show that:

- The presence of modern materials close traditional ones was detected also in this building. The columns and some parts of the ledges are made of cement-based materials, but other parts of the same ledges and even the columns' plinths are made of quarried, sculptured sandstone (Fig. 9).
- The cement-based columns and ledges are in a good state, despite the site severe pollution. These precast elements were usually manufactured pouring a first, fine cement mortar layer (some cm thick) into moulds and then, after some curing, casting ordinary cement concrete (with suitable steel reinforcements) up to complete mould filling [36]. Thus, the external, strong and compact layer not only resembles natural stone, but has been protecting the internal reinforcement against environment during years. This external layer can be observed in Fig. 10, where an accidental detachment occurred.
- On the contrary, the local sandstone used in the building, characterised by a high carbonates content (about 65 wt %) and significant fractions of silica and feldspars, is deeply decayed (Fig. 9). Due to atmospheric pollutants, leading to acid and sulphatic attack [37], the deteriorated zones show a lower amount of carbonates (about 47 %) and a meaningful content of sulphates (about 0.5 wt %) in the sheltered zones. Where the decayed stone ledges were repaired with cement mortars during last decades, pop-out is presently appearing.
- Likewise to the Palazzina Liberty, a weaker and less durable material, the sandstone, has been used as base of the concrete precast elements, e.g. the columns in the façades (Fig. 9-10).

Unlike the Palazzina Liberty, the fired clay bricks exhibited a significant $CaCO_3$ content (1÷6 wt %) and high porosity (about 30 %), revealing the material's low firing temperature and quality. Also the hydraulic mortar joints are of low-quality and very poor in binder, as confirmed by the historical documents: workers' turmoil and frequent strikes at the time of construction caused the use of some second-rate materials. Finally, no *sagramatura* was detected on the facades.

Figure 10: The Sacro Cuore church: an occasional detachment of the external mortar layer in a concrete column and its sandstone basis

4 Conclusions

1. The comparison of the three buildings showed that the age between the end of XIX and the early XX century was actually characterised by a passage from tradition to innovation in architecture. However, analyses and investigation of the construction materials disclosed that actually this passage occurred with different features in Aveiro and in Bologna: in Portugal traditional materials were used with nonchalance to give expression to the novel architecture, while in Italy new materials and traditional ones were employed side by side, sometimes with unusual outcomes. These differences are due to the way the architects interpreted the novel architecture for each specific construction, taking also into account the local availability of building materials, suitable workmanship and often using "poor", low-cost, local materials to emulate "noble" or fashionable ones, as, to tell the truth, in ancient ages. Hence the *Art Nouveau* imperative of local construction techniques and materials as a way to contrast classicism and favour renovation was naturally followed: in the paper it is proven that this may be disclosed not only by architectural and historical analyses, but ascertained also by proper and careful study and characterisation of the construction materials and modes.
2. Finally, the investigated *Art Nouveau* monuments highlight that the route to restoration must borrow the same basic diagnostics principles of ancient architecture, but self-adjusting to the unavoidable and theoretically unpredictable differences in materials and construction technologies throughout Europe. Indeed, a reliable knowledge of the existing materials is compulsory for the restoration of classical and modern architecture, but it is often neglected nowadays in the latter case: recent buildings restoration is often performed with poor attention to the existing materials, e. g. removing interesting parts or materials, cancelling native surface textures or even using not compatible materials, which damage the original ones, thus cancelling the image itself of a period which, although turbulent and waving, led to important architectural experiences and subsequent developments. Hence, taking into account the different ways in which modern architecture developed locally, common conservation/restoration strategies should be agreed upon in Europe for an effective safeguard of this cultural heritage [21]. This should promote suitable techniques and workmanship for restoration/maintenance of this architecture respectful of its vicissitudes: further studies on European buildings of the same architectural current are therefore in progress.

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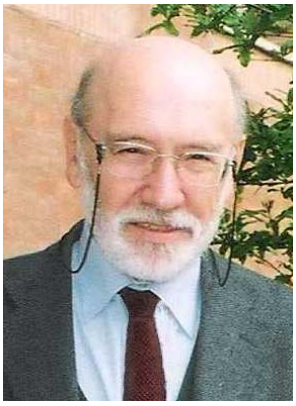

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